

Profiling Float Observations in the Aegean Sea

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LONG-TERM GOALS

The long-term goal of this work is to gain a better understanding of mixing and water mass formation processes in semi-enclosed basins, using modern profiling techniques to monitor the evolution of the stratification in various sub-basins of the Aegean Sea.

OBJECTIVES

The main objective of this work is to collect a large number of high quality temperature and salinity profiles and create a continuous long-term record of the characteristics of the water column in the major deep basins of the Aegean Sea, an area of high complexity and strong variability at various time scales. The results of these measurements can contribute significantly to our understanding of the seasonal and interannual variability of the circulation and water mass characteristics in the region as well as to the connection between the different sub-basins. More specifically, the project is aiming to:

1. Produce an updated climatology of water mass structure in the larger sub-basins of the Aegean Sea
2. Monitor patterns of the seasonal and interannual variability in the water mass structure, the circulation and water mass formation of the region
3. Create a valuable data set for numerical model initialization and assimilation used by the operational near real time models of the region

APPROACH

During the second year of the project the last two profiling floats were deployed in the Aegean Sea (a total of four profiling floats were deployed in the framework of the current project). These floats are APEX-style profiling floats with SeaBird CTD sensors, constructed at the University of Washington under the supervision of Prof. Stephen Riser. The parking depths of the first profiling floats were relatively close to the bottom. Due to the very irregular topography of the Aegean Sea, the parking depth proved to be extremely high for safe profiling in the region and the strategy for the last two profiling floats included much smaller parking depths and the "park and profile" technique to monitor the deeper water masses. The parking depths were selected at intermediate depths (400 m) to decrease malfunction possibilities (observed in the first two profiling floats) and the profile depth at 1000m in order to measure the biggest part of the water column. All four floats were deployed in close

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collaboration with the Hellenic Center for Marine Research (Senior Research Scientist Alexander Theocharis) by the R/V Aegean (which is owned and operated by the HCMR). The data acquired by the profiling floats are complemented by standard in situ CTD surveys using R/V Aegean, in the areas of the float deployment and key locations of the Aegean sub-basins. Results from both profiling float observations and CTD surveys are compared with historical data in the region and results from existing operational models and used for improved initialization and assimilation procedures.

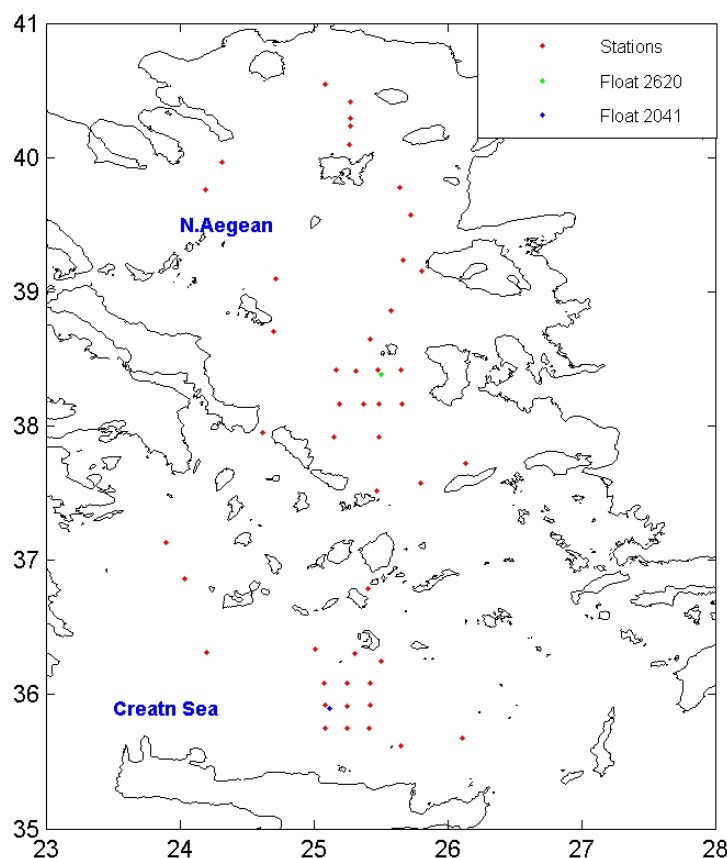


Figure 1. Profiling float deployment sites (float 2620 green dot; float 2041 blue dot) and CTD stations (red dots) occupied during Cruise II of the project

WORK COMPLETED

1. The second cruise (Cruise II) in the framework of the project was carried out aboard the R/V Aegaeo during February 3-13, 2006. The shipboard scientific activities consisted of the deployment of the two profiling floats (No 2620 and No 2041, prepared by the University of Washington – PI: S. Riser) and a hydrographic survey in the areas of deployment as well as on several key locations of the various sub-basins. The sites of the deployment were chosen at the Chios basin in the central Aegean and the central Cretan Sea. A total of 47 hydrographic (CTD) stations were occupied on the cruise. The float deployment and stations locations are plotted in Figure 1. At each station, profiles of temperature, salinity (conductivity), and dissolved oxygen concentration were collected using a Sea-Bird CTD system.

2. Profiling float observations in the Aegean Sea are presented in near real time on <http://runt.ocean.washington.edu/uoa/> constructed and maintained by the University of Washington. Figure 2 presents the four float trajectories in the Aegean Sea. The profiling float deployed in the central Cretan Sea (No 2041) was grounded on the Cretan island shelf. The float was recovered by HCMR speedboat and is now tested, in order to be redeployed.

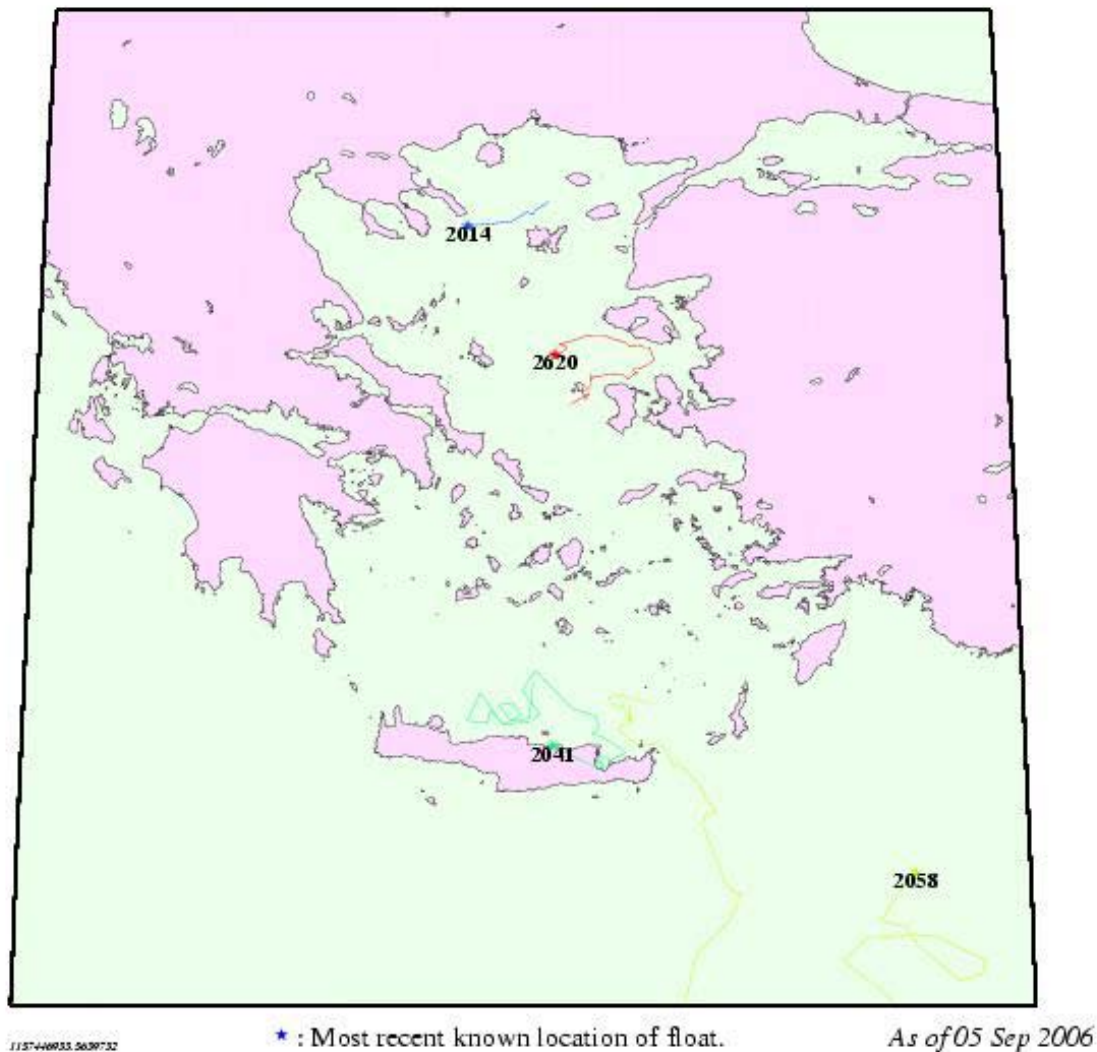


Figure 2. Float trajectories in the North Aegean (2014 - blue line), Chios basin (2620 - red line), eastern Cretan Sea and Levantine (2058 - yellow line) and central Cretan Sea (2041 – green line).

3. Analysis of both profiling float and hydrographic observations is being performed. The results are compared with historical data in order to evaluate changes in the water column structure of the Aegean Sea, an area with very strong interannual variability. The observations are also being used for operational system evaluation/tuning.

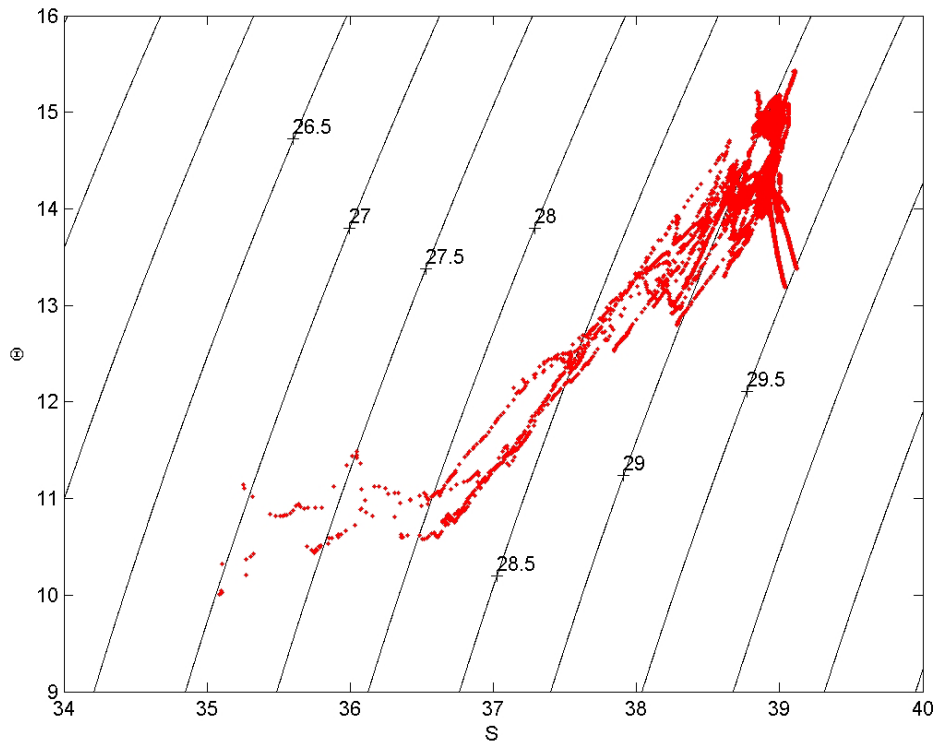


Figure 3. Temperature/salinity characteristics measured during the hydrographic survey of Cruise II.

RESULTS

The work performed in the framework of the project revealed several important findings, including the following:

- The variability of temperature and salinity characteristics at the surface, intermediate and deep levels is very large. At the surface layers this can be attributed to the presence of the Black Sea Water in the northern basin (inflowing to the Aegean from the Dardanelles strait with very low temperature and salinity), while in the Cretan Sea surface waters are influenced by the warmer and more saline waters of Levantine origin. Remarkable differences occur also in the intermediate and deep layers, even at sub-basins located very close to each other. It becomes evident that the basin scale circulation interacts with the sub-basin scale and mesoscale dynamics (largely influenced by the complex topography of the region) creating a complex circulation and stratification pattern. The results from the cruises and float observations are currently compared with model results, for validation purposes and in order to identify patterns and mechanisms of the regional dynamics.
- Another noteworthy result is the very large variability observed during the two cruises (CRUISE I and II), that took place almost the same time of the year. Figures 4 and 5 present temperature and salinity profiles from the CTD stations occupied at the deepest points of the north and south Aegean Sea during both cruises (the location of the first two profiling float deployments). The stratification and water mass characteristics present large differences, associated with water mass formation and changes in the circulation patterns and exchanges between various sub-basins.

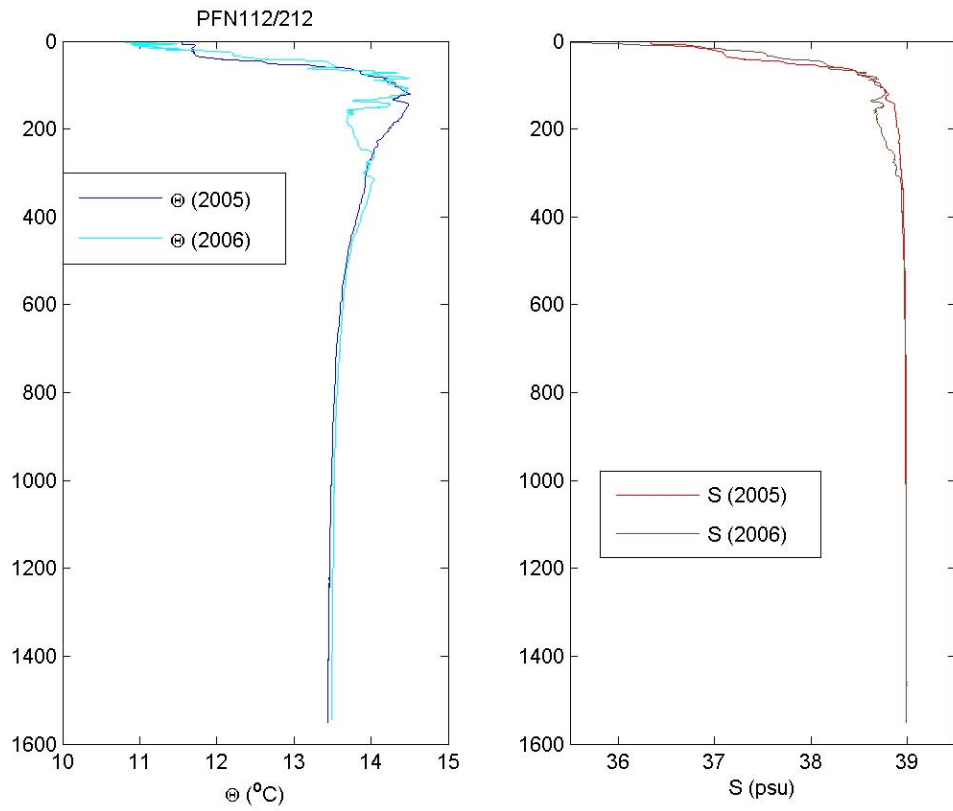


Figure 4. CTD profiles at the deepest location of Limnos basin (North Aegean) acquired during CRUISE I (March 2005) and Cruise II (February 2006).

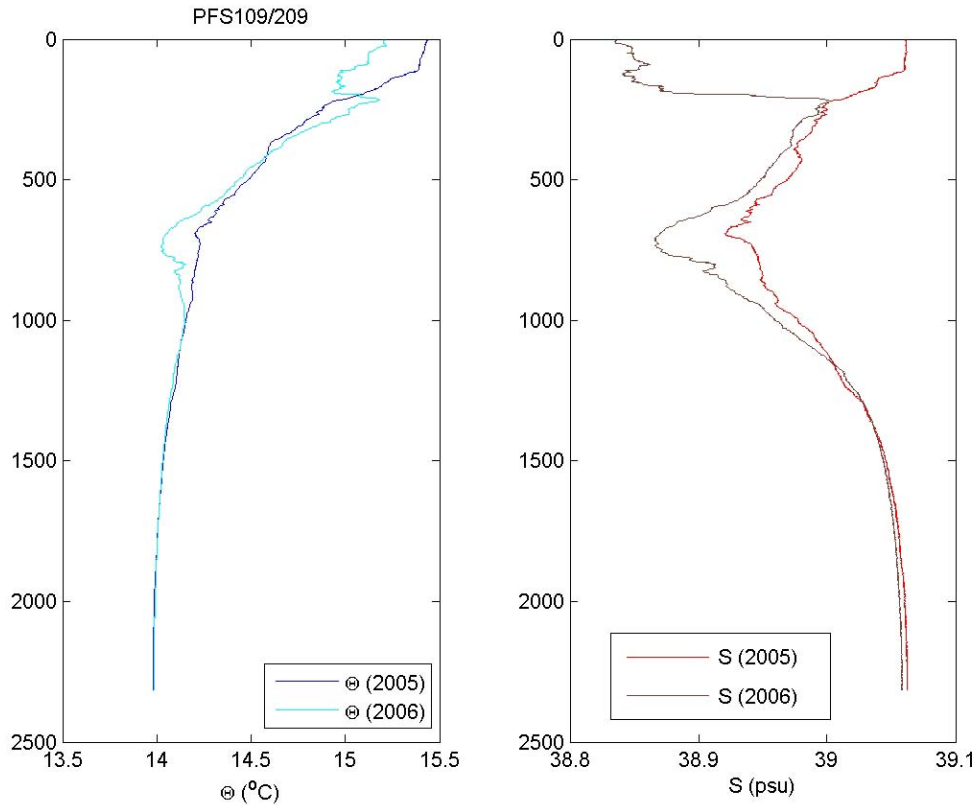


Figure 5. Comparison of CTD profiles at the deepest location of Cretan Sea (South Aegean) acquired during CRUISE I (March 2005) and Cruise II (February 2006).

- These results were investigated in relation to the Eastern Mediterranean Transient (EMT - Roether et al., 1995; Theocharis et al., 1999), that characterized the thermohaline circulation and the deep-water hydrological properties of the eastern Mediterranean Sea during the late 80s. The Aegean Sea, during EMT, became the new more effective source than the old one, since it produced not only denser water, namely the Cretan Deep Water (CDW), but also higher volumes. From 1988 to 1995, massive outflow of CDW occurred through the Straits of the Cretan Arc towards the Ionian and Levantine basins. The CDW being of particularly high density (29.3 kg/m³) sank into the near-bottom layers, uplifting the older deep waters of Adriatic origin and affecting the exchange between the Aegean and the adjacent basins. Since 1995, the event started to decay, but the rate of the Eastern Mediterranean system relaxation as well as its final state (old or modified) remain still unclear. Data acquired in the framework of the project in the Cretan Sea reveal a relatively less saline intermediate layer centered at around 800m. Its origin is the deep-water lying between Levantine Intermediate Water and Eastern Mediterranean Deep Water, namely the Transitional Mediterranean Water (TMW), which was present in the Cretan Sea shallower levels (200-600m) during the first stages of EMT. Comparison with older observations (Theocharis et al., 2006) indicates important changes associated with mixing processes within and outside the Aegean and a possible evolution of the exchange between the Cretan Sea and the Levantine basin (Figure 6 and 7). The Aegean outflow that contributed to the Eastern Mediterranean shallower layers (1500-2500m), during 1998-99, has been obviously minimized.

This current phase is characterized by the inflow of the TMW, at least through the deepest strait of Kassos, which was crossed by profiling float No 2058 (Figure 7). Finally, the waters just outside the Eastern Cretan Straits, below 1000m, are a mixture of deep water of Adriatic and Aegean origin, with the former contributing to a higher percentage compared to earlier observations (Figure 8).

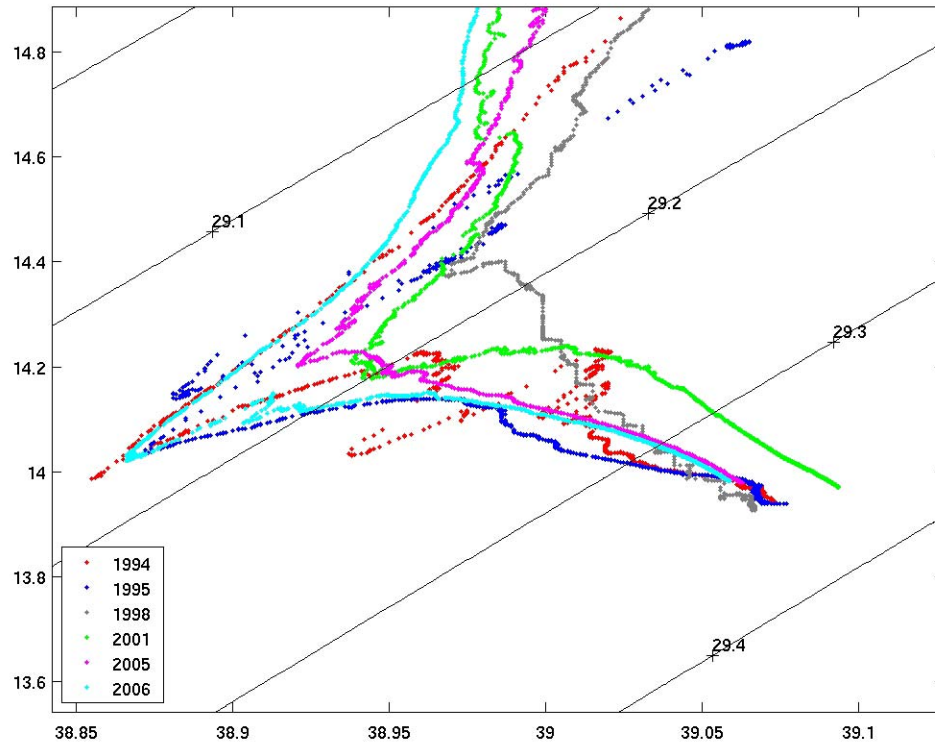


Figure 6. Potential temperature/salinity characteristics from CTD stations occupied in the deep depression located in SE Cretan Sea during various years between 1994 and 2006. Very strong variability is observed at the salinity minimum layer, corresponding to the Transitional Mediterranean Water (TMW). This water mass is related to the Eastern Mediterranean Transient observed in the Aegean Sea region in the late 80s and early 90s.

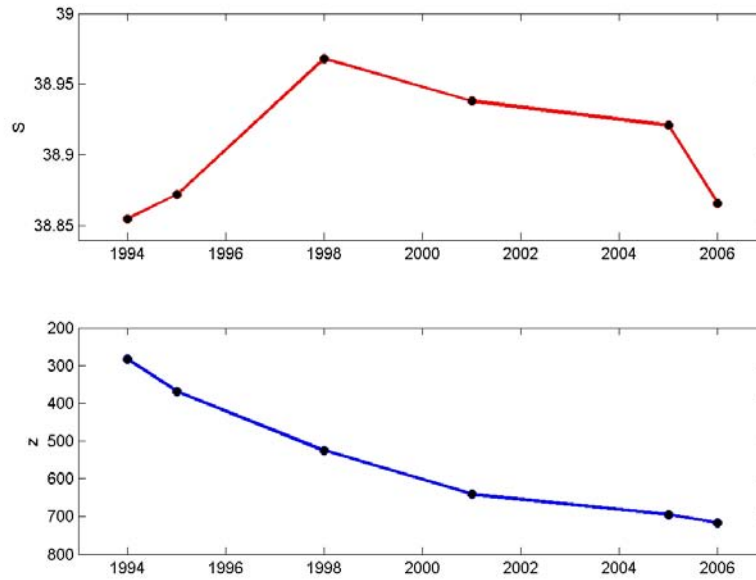


Figure 7. Time evolution of the salinity (upper panel) and depth (lower panel) of the salinity minimum at the deep depression located in SE Cretan Sea (1994 - 2006).

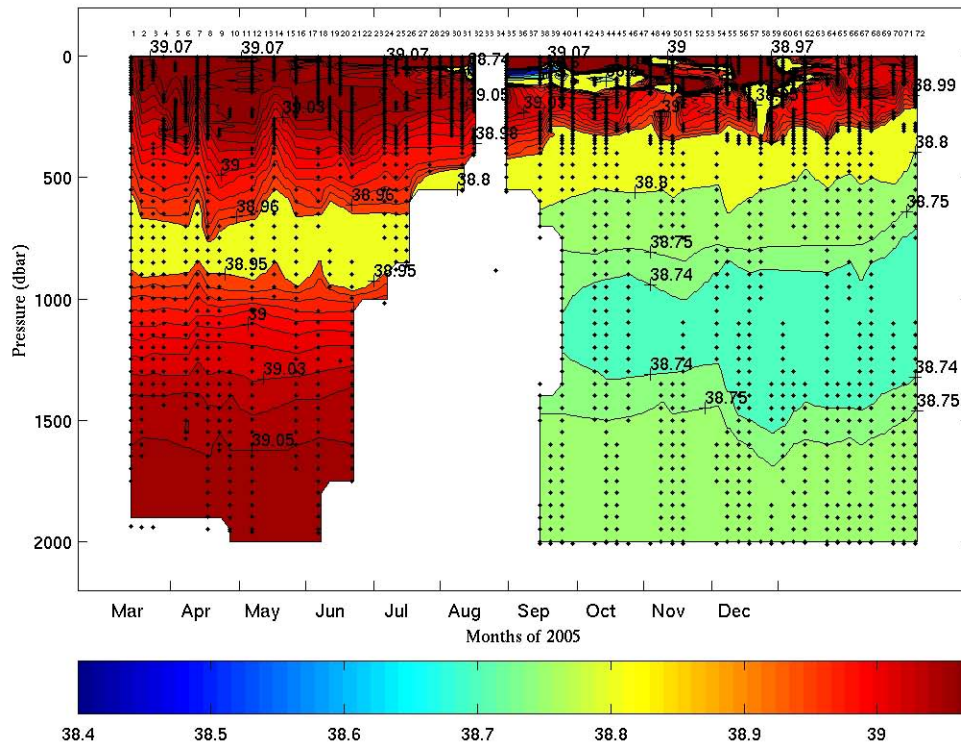


Figure 8. Salinity profiles acquired by profiling float No 2058 following its trajectory in the Cretan Sea and the Levantine basin. The shallow part observed during summer 2005 is related to its passing through the Cassos strait. The salinity minimum center around 800m depth in the Cretan Sea (left part of the figure) can be traced at the deeper parts of the strait and around 400 m in the Levantine Sea.

- Finally, an important contribution of the project is the testing of the deployment and sampling strategies for profiling float observations in a very complicated marginal basin, such as the Aegean Sea. The Aegean Sea coastline is very irregular and its topographic structure very complicated. There are over 3,000 islands of various sizes scattered all over the basin. The area also presents high seasonality, strong circulation patterns, strong forcing and is a very busy waterway for recreation and commercial ships. All these make the Aegean a difficult but also ideal place for testing Lagrangian observation strategies. The problems in the performance of the first two floats showed that very deep parking depth can not ensure the trapping of the profiling floats inside basins and can be dangerous for the instrument's performance. The new sampling strategy ("park and profile") improved the instruments' performance without minimizing the problems encountered. Under the supervision of University of Washington, the experience gained during the project will be summarized and the results may contribute to the oceanographic community.

IMPACT/APPLICATIONS

This is the first coordinated effort to study the Aegean Sea with modern profiling floats. It gives a unique opportunity to acquire a long-term data set of the characteristics of the various sub-basins in the region and give new insights of the dynamics and their variability. Additionally, the technical performance of the profiling floats will be tested in a very complicated environment with extremely irregular topography and strong seasonal and interannual variability in circulation and stratification. Eventually the data will be used for assimilation into operational models. A graduate student is working on this project, and it is using the results for his PhD dissertation.

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